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Strains of Flue-Cured Tobacco Resistant
to Black Shank

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MEETING AN URGENT NEED

Black shank, one of the most destructive of tobacco diseases, is a serious menace to tobacco culture in the western part of the flue-cured producing area of North Carolina and Virginia and is threatening to become serious in the central and eastern parts. Caused by a soil-inhabiting fungus, this disease, under favorable conditions, can attack the tobacco plant at any stage of growth. Once established in the soil it usually spreads rapidly.

Four strains of flue-cured tobacco resistant to this disease are now available and have been given the names Oxford 1, Oxford 2, Oxford 3, and Oxford 4. Described here, they are at this time recommended for use only where the disease is present; in such areas, however, they

provide a means both for conserving the farm labor that is wasted when disease destroys crops and for avoiding serious losses in the production of an important item in military provisions.

As a first step in seeking material resistant to black shank, 66 flue-cured varieties, strains, and selections were tested, but none proved resistant. Two varieties of ordinary tobacco and three varieties of rustica tobacco obtained from Russia, however, were highly resistant, and two dark fire-cured hybrids proved moderately so. Four strains of cigar-wrapper tobacco developed and supplied by the North Florida Experiment Station were found highly resistant under Old Belt conditions in North Carolina, and one of these, known as 301, was crossed with standard flue-cured varieties. By following the procedure of selfing, selecting, and back-crossing to the flue-cured parents, the four fairly uniform strains resistant to black shank have now been obtained. These conform well with the flue-cured type and possess good quality.

Although the new strains need to be somewhat further improved with respect to uniformity and quality of leaf, they are considered to be suitable for meeting the immediate urgent need for resistant types in the flue-cured producing areas where black shank is prevalent.

A SERIOUS PROBLEM

The fact that entire plantings may be destroyed by black shank creates a serious problem for tobacco growers, especially those who have limited areas suitable for production. The problem is complicated by the ease and rapidity with which the disease spreads. Outbreaks in North Carolina during the last few years indicate that within a very short time it may spread over the entire Old Belt (western Piedmont). As a result of localized outbreaks, flue-cured tobacco is being menaced in the Middle Belt (eastern Piedmont) and the New Belt (Coastal Plain).

The disease has been reported in Brazil, Guatemala, Jamaica, Nyasaland, the Philippine Islands, Puerto Rico, Java, Mauritius, Rumania, Bulgaria, Argentina, Uganda, Trinidad, Japan, and Formosa. In the United States, it is known to occur in Florida, Georgia, Alabama, North Carolina, Virginia, Kentucky, and Tennessee. Its first appearance in the flue-cured tobacco area of North Carolina was about 1915 in the vicinity of Belew Creek, Forsyth County, but it was not identified and did not cause general alarm until 1930. By 1932 several isolated centers of infection had become established in other parts of Forsyth County, as well as in the adjoining counties of Guilford, Rockingham, Surry, Stokes, and Alamance. In 1941 the disease was general in the counties named and in addition had spread to Person, Davidson, and Pitt Counties, or about 200 miles from the nearest previously known disease center. During 1937 it was carried into Mecklenburg County, Va., on diseased plants obtained from the black-shank-infected area in Pitt County, N. C., and later it was found in Pittsylvania and Halifax Counties, Va.

CAUSE AND SYMPTOMS OF BLACK SHANK

Black shank is caused by a soil-inhabiting fungus technically known as *Phytophthora parasitica* var. *nicotianae* Tucker. Under favorable conditions the fungus is capable of attacking the tobacco plant at any stage of growth. Temperature may determine, to a large extent, the rapidity with which it develops. In the seedbed the fungus usually attacks the roots of the seedling or the basal por-

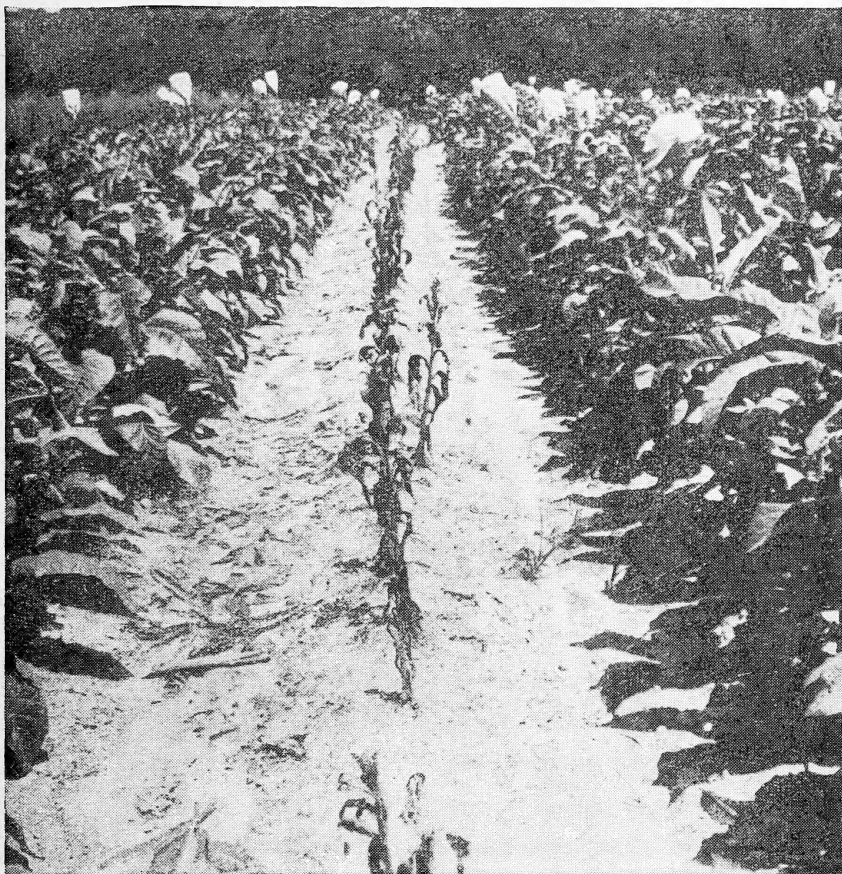


FIGURE 1.—Center, row of a susceptible flue-cured variety, showing wilting and dying of plants attacked by black shank; right and left, resistant strains possessing flue-cured characteristics, obtained by crossing susceptible flue-cured varieties with resistant Florida cigar-wrapper variety 301 and backcrossing to the flue-cured parent varieties.

tion of the stalk at or near the surface of the soil. The stems and roots of diseased seedlings appear swollen at first and later turn brown, and in a very few days the plants fall over. In older plants, the fungus usually first attacks the taproot or main laterals and then rapidly invades the basal portion of the stalk; the plant may wilt and die, however, before any darkening appears on the stem above

the soil level. Generally, there is a sudden wilting of the whole plant, and rarely does it revive after once wilting (fig. 1). The roots and stalk turn brown soon after the tissue is killed, and the appearance is that of a dry rot. The pith in the diseased area of the stalk usually separates into disks, unless the soil is very moist or a period of high humidity prevails immediately after the plant dies. At the time of wilting, the plant tissue above the infected area appears healthy, and little or no discoloration is evident; within a short time, however, the leaves and stalk become brown and dry. The dead stalks usually remain upright (fig. 2).

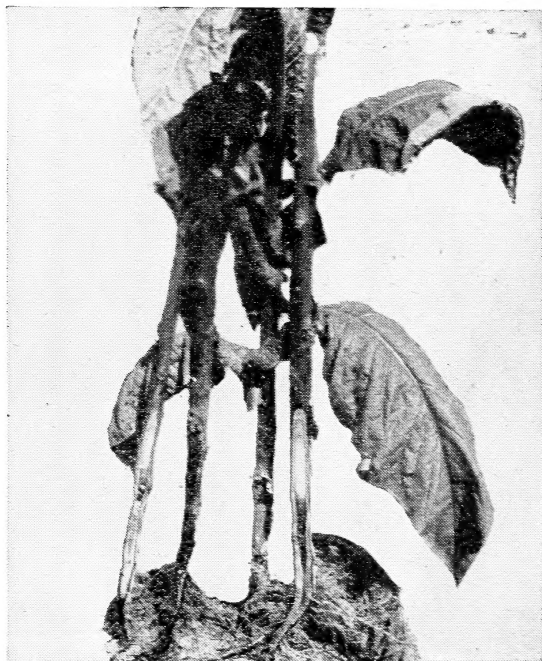


FIGURE 2.—Tobacco plants affected with black shank, showing discoloration of the stem and the drying of the pith in diaphragmlike plates.

The leaves, especially the lower ones, may become infected during prolonged warm, humid periods. Infected areas appear as circular spots, pale green at first and later showing a light-brown center with a pale-green zone nearer the healthy tissue. The spots are usually an inch or more in diameter and in many cases may cover a large part of the leaf. On the cured leaf they are light brown and lifeless. Occasionally lesions develop on the stalk well up from the ground. This usually results in the sudden wilting and collapse of the plant.

DISSEMINATION

Once the fungus becomes established in the soil, its spread is usually rapid. Within localized areas its spread has been largely brought about by drainage water and by movement of soil from contaminated to uncontaminated areas of the field or onto clean fields. This is often

accomplished by the soil adhering to implements and tools used in cultivation and to the feet of work stock and men. Other means of spread include the use of diseased plants for transplanting, application of contaminated manure or diseased tobacco scrap and stems to the soil, and the use of contaminated water on plant beds or in the operation of transplanting in the field.

Spread to new centers of infection has probably been brought about by contaminated drainage water, the use of diseased plants from infested seedbeds, movement of contaminated soil on road machinery and on other heavy equipment going from one section to another, or the use of diseased tobacco scrap or stems.

TESTING FOR DISEASE-RESISTANT PARENTS

Prior to 1930 no attempt had been made to develop resistance to black shank in flue-cured tobaccos. At that time, seeds of 66 flue-cured varieties, strains, and selections were collected at the Tobacco Experiment Station, Oxford, N. C., and seeds also were obtained of varieties representing the dark fire-cured, Burley, and Turkish types and the species *Nicotiana rustica* L. Tests conducted during 1931 in the vicinity of Walkertown, N. C., on heavily contaminated soil showed that there was little or no resistance to the black shank organism in flue-cured tobaccos. Two varieties of *N. tabacum* L. (ordinary tobacco), three varieties of *N. rustica* L., from Russia, and a variety of the Cuban type known as Cuban High Nicotine were highly resistant. Two dark fire-cured hybrids developed for black root rot resistance were fairly resistant to black shank. All these resistant types had leaf, stalk, or other characteristics very different from flue-cured tobaccos, and none was considered suitable for use in making crosses on flue-cured varieties.

Of four strains of cigar-wrapper tobacco developed by the North Florida Experiment Station and tested during 1932, three showed a high degree of resistance under the local conditions. One of these (301) has proved very useful in developing resistant varieties suitable for flue curing.

DESCRIPTION OF PARENT STOCKS

While a number of crosses were made, only those hybrids were continued that showed most promise for resistance and possessed desirable characteristics of the flue-cured type. The parents of only those strains that have shown most promise are here described. The flue-cured parentage includes four varieties: Virginia Bright Leaf, White Stem Orinoco, Warne, and 400.

Virginia Bright Leaf.—This variety has a rather wide range of adaptability and is grown with good success over most of the flue-cured area. The leaves are fairly broad and taper to a moderately sharp point. They are about three-fifths as broad as long, and the broadest region is about one-third the distance from the stem end to the tip. The leaves grow semiupright and are moderately spaced on the stalk. The date of maturity is about average for flue-cured varieties, and the yield is satisfactory. It is a medium-bodied tobacco.

White Stem Orinoco.—This variety before reaching the topping stage somewhat resembles a cedar tree in shape. The leaves are

about two-thirds as broad as long, taper to a sharp point, and have small fibers, fine texture, and good body. They have an upright habit of growth prior to topping and are fairly closely spaced on the stalk. The variety is adapted to the less productive and sandy loam soils of the Middle and Old Belts of North Carolina and Virginia, but not to the heavy and more fertile soils. On these latter the leaves are coarse and do not ripen uniformly. It is noted for producing bottom leaves of good size.

Warne.—This is an old cutting variety and was grown until recent years in the Old Belt, where the bulk of the flue-cured wrappers is produced. The leaves are about half as broad as long, droop slightly, and are widely spaced on the stalk. It matures later than most flue-cured varieties and tends to produce an orange-colored leaf of heavy body.

400.¹—Selected from a cross, supposedly of Harrison Special and Silk Leaf, this variety is resistant to black root rot (*Thielaviopsis basicola* (Berk. and Br.) Ferr.) under North Carolina conditions. The plants make rapid and vigorous growth, producing large, broad leaves with a blunt point. The leaves are thin and cure bright from the bottom to the top of the plant if allowed to ripen fully before being harvested. This variety is especially well adapted to the Middle and Old Belts of North Carolina and Virginia. It grows with a yellowish cast and is a heavy yielder of high-quality cigarette smoking tobacco.

Of the four strains of the resistant cigar-wrapper type tested, only one (301) was used to introduce resistance into the flue-cured type. The other strains had objectionable characteristics, such as small leaf number, short internodes, short blunt leaves with large auricles, excessive sucker growth, and a splitting of the seed pods upon maturity, allowing the seed to shatter.

301.—A cigar-wrapper strain highly resistant to black shank, developed from a cross of resistant Big Cuba with resistant Little Cuba.² This is a fairly tall growing variety with a large number of leaves, which are very similar in shape to flue-cured tobacco, but only about half as large. They are rather widely spaced on the stalk and have small auricles. The stalk is rather small for the size of the plant. The variety is susceptible to both frogeye (*Cercospora nicotianae* Ell. and Ev.) and brown spot (*Alternaria longipes* (Ell. and Ev.) Tisdale and Wadkins). When flue-cured, this variety does not produce a bright color, nor does it possess the desired taste, aroma, texture, and body for flue-cured leaf.

DEVELOPMENT OF RESISTANT STRAINS

During the summer of 1932, 301 and other cigar-wrapper strains were crossed with Virginia Bright Leaf, White Stem Orinoco, Warne, and other flue-cured varieties. The F₁ plants were grown and self-pollinated in the greenhouse during the following winter. Later, all of the crosses made at this time were discarded except 301 × Warne and Warne × 301, Virginia Bright Leaf × 301, and White Stem Orinoco × 301.

¹ MOSS, E. G., and BULLOCK, J. F. TWO NEW VARIETIES OF FLUE-CURED TOBACCO, 400 AND 401. N. C. Agr. Expt. Sta. Bul. 337, 8 pp., illus. 1942.

² TISDALE, W. B. DEVELOPMENT OF STRAINS OF CIGAR WRAPPER TOBACCO RESISTANT TO BLACK SHANK. (PHYTOPHTHORA NICOTIANAE BREDA DE HANN). Fla. Agr. Expt. Sta. Bul. 226, 45 pp., illus. 1931.

All later breeding and selection work was conducted in the field on soil heavily contaminated with the black shank parasite. The check rows planted with susceptible varieties were usually killed before the middle of the growing season. After the original cross, in most cases, the plants were self-pollinated and selected for three or more generations, or until a fairly uniform line for type and resistance could be obtained. In making selections, quality was always considered, since resistance without quality would be valueless from a commercial standpoint. Plants exhibiting the most desirable flue-cured characteristics and at the same time having adequate resistance to black shank were selected for future testing. At the time the seed was harvested, the seed plants were pulled and the roots and stalks examined to determine the extent, if any, of black shank infection. Lines uniform for resistance (95 percent or better) and type were obtained after five to seven generations of selfing and selecting, but the type was more nearly that of the resistant parent, and these lines were not used for backcrossing.

In 1935 a number of the most uniform F_1 and F_4 lines showing a high degree of resistance were backcrossed to the flue-cured parent. In the F_2 and F_3 generations following the first backcross it was easy to find plants showing a greater number of flue-cured characteristics than the resistant parent, but the degree of resistance in these plants was generally lower. A few strains with fairly high resistance were selected (fig. 1). Physical characters, as shade of flower color, size of stalk, angle of leaf fibers, shape of leaf, smoothness of leaf, drooping or upright habit of leaf growth, and suckering habit, were valuable aids in selecting for flue-cured type. Strains of unusually high resistance were developed by crossing first backcross uniform strains of 301 \times Virginia Bright Leaf with 301 \times White Stem Orinoco.

Second backcrosses to the flue-cured parent were made in 1938. The selecting and selfing process was repeated. A few plants having very desirable flue-cured characteristics in the F_2 generation were again backcrossed to the flue-cured parent. In the following season, F_2 's from the second backcross and F_1 's from the third were planted in the field. When the second backcross F_2 's produced F_4 lines fairly uniform for type and resistance, they were continued, along with selections from the related third backcrosses. Inbred lines have not yet been obtained from the third backcross selections.

Seven of the most uniform F_4 lines of the first backcross were planted in 1939 in the variety trial tests at the Tobacco Experiment Station at Oxford. The results indicated a satisfactory yield, and the quality appeared to be fairly good. Chemical analysis indicated that from the standpoint of flue-cured tobacco the leaf produced by these lines was only of moderately good quality. In field trials made during 1942, four second backcross lines of the F_4 generation proved to be superior to the first backcross lines tested during 1939. The quality compared favorably with that of the better flue-cured varieties.

Since black root rot is a disease of considerable importance in the flue-cured tobacco areas of the Piedmont, suitable flue-cured varieties resistant to both this disease and black shank are highly desirable. With a view to obtaining such varieties, 400, which is a root rot resistant strain, was crossed with 301 during the season of 1935. Applying the procedure of selfing and selection, fairly uniform lines



FIGURE 3.—Typical plants of three new strains of flue-cured tobacco resistant to black shank. The resistant parent was cigar variety 301, and these strains, designated as Oxford 1 (A), Oxford 4 (B), and Oxford 3 (C), are F_4 selections of second backcrosses to the flue-cured varieties Virginia Bright Leaf, Warne, and White Stem Orinoco, respectively.

possessing resistance to both diseases have been obtained. Similar results have been obtained by crossing 400 on third generation second backcross lines having as flue-cured parents such varieties as Virginia Bright Leaf, White Stem Orinoco, and Warne. None of these, however, is yet ready for release.

STATUS AND DESCRIPTION OF RESISTANT STRAINS

Many growers have only limited areas on their farms suitable for growing tobacco of good quality, and with these fields contaminated with the black shank parasite, they face the possibility of complete loss of the crop if ordinary flue-cured varieties are planted. In view of the urgent need of effective control of the disease, particularly under present emergency conditions, it is felt that certain of the F₄ selections from second backcrosses to Virginia Bright Leaf, White Stem Orinoco, and Warne possess sufficient disease resistance, yielding capacity, and quality and are sufficiently stable to justify their release to growers. The following brief descriptions will indicate the chief growth characteristics of these strains:

Black Shank Resistant VBL-Strain 1 (Oxford 1).—This strain (fig. 3, A) can hardly be distinguished from the flue-cured parent, Virginia Bright Leaf. The leaves are smooth, fairly thin, fine-textured, and about three-fifths as broad as long, with the broadest area situated about one-third the distance from the base of the leaf to the tip. They are spaced at fairly wide intervals on the stalk. This strain has ample spread and grows with a slight yellowish cast. It should not be harvested until fully mature.

Black Shank Resistant VBL-Strain 2 (Oxford 2).—This strain is similar to strain 1, above, although the leaves are somewhat smaller and more closely spaced on the stalk. Also, they are less smooth and have a deeper shade of green. They appear to be slightly thicker and when cured have slightly more body.

Black Shank Resistant WSO-Strain (Oxford 3).—This strain (fig. 3, C) has a leaf very similar to that of the flue-cured parent, White Stem Orinoco. The stalk is small and the leaves are widely spaced on the stalk. The leaves are smooth and very fine-textured and possess good body. They are not so large as those of the Virginia Bright Leaf strains.

Black Shank Resistant W-Strain (Oxford 4).—The growth habits of this strain (fig. 3, B) are very similar to those of the flue-cured parent, Warne, the main difference being that the hybrid grows with a slightly lighter green color; and the cured leaf possesses somewhat less body. The leaves are spaced at moderate intervals on the stalk and droop slightly.

These strains are recommended for growing only on farms where black shank is present. In suggesting their use at this time to meet pressing needs it is recognized that they are in need of further improvement with respect to quality and uniformity of product. It should be possible by judicious selection and testing to obtain within 2 or 3 years strains producing a leaf of high quality and resistant to both black shank and black root rot.

